advisability of endeavouring to go so far. We are as yet far too ignorant of the nature of the relations existing between cytoplasm and nucleus to be able to draw any safe general conclusions respecting them. What we do know suffices to prove that, probably as the result of interchange of material, the relations are at least of a very intimate nature.

It is, of course, impossible within the limits of so short a notice to attempt to do anything like full justice to the skilful treatment that Prof. Verworn has brought to bear on his subject. It must suffice to repeat that it is thoroughly well worth reading, and whatever may be thought of the tenability of the hypothesis itself, one can hardly deny that it does fulfil the important condition of enabling one to link together in a suggestive manner a large number of very complicated phenomena.

SCIENCE AND PRACTICE.

The Lighthouse Work of Sir James Chance, Bart. Pp. x + 162. (London: Smith, Elder and Co., 1902.) Price 5*s*. net.

THE optics of lighthouse lenses form a sufficiently fascinating subject, and its interest, apart from its practical importance, has attracted able men from Augustin Fresnel down to John Hopkinson. Among these, James Timmims Chance deservedly holds a prominent place, and his biographer has earned our thanks by the account he has given in the pages under notice of Chance's life and work.

Sir James Chance, a son of Mr. William Chance, of Birmingham, one of the partners in the glass-making firm of Chance Bros. and Co., was born in 1814. After gaining honours in various subjects, including Hebrew, at University College, London, he entered Trinity College, Cambridge, and in 1838 he graduated as seventh wrangler. Immediately after this he entered his father's firm, of which he remained a partner for fifty years, being head of the firm for twenty-five. He was made a baronet by her late Majesty on the occasion of her last distribution of birthday honours. He died on January 6, 1902.

In old days, parabolic reflectors were used for lighthouses; the employment of lenses is due to Augustin Fresnel, who in 1819 erected the first dioptric system at the Tour de Cordouan; the system was extended by his brother Leonor and other distinguished men in France, and in Great Britain by the family of Stevenson, by Airy and by Faraday. With the two latter Mr. Chance became intimately associated about the year 1859.

His firm had manufactured lighthouse lenses for some years previously. Before this, the industry had been crushed out in England by Excise regulations; an Order in Council was required to permit of their manufacture, and a duty amounting to some 300 per cent. on the cost of the glass was enforced. In consequence, Messrs. Swinburne and Co., of South Shields, who for a few years had manufactured lenses, gave up the work in 1845. In 1850 Messrs. Chance took it up. They engaged a French expert, M. Tabouret, who had worked for Fresnel himself, and he exhibited in the Exhibition of 1851 an apparatus of the first order, made at Messrs. Chance's Spon Lane works. In the years that followed, the work prospered, the plant was increased and the optical part of a number of lighthouses was manufactured. M. Tabouret left the firm in 1853.

In 1859 the work of the Commission to inquire into the condition of the lights, buoys and beacons of the United Kingdom began. Airy and Faraday had charge of the scientific side of the inquiry. Mr. Chance's assistance was called in as a manufacturer of great experience, and it was soon found that in him the Commission had an adviser who could render services of the highest value. His mathematical training enabled him to understand and develop the theory of the subject, his practical experience showed him what was possible. He had already introduced improvements into the method of grinding the annular lenses which form the system, and its various components had reached a high degree of perfection.

But, though this was so, the distribution of light effected by means of the lens system was, in many cases, entirely wrong. At that time Messrs. Chance were not allowed even to tender for the frames to hold the lenses, although they had to make these in order to adjust the system in their workshop. They had no share in the erection or adjustment of the light, which was done usually by contractors with little or no optical knowledge, and the result was failure. One of the most glaring instances was the Whitby light, of which Airy reported:—"The dioptric part of the apparatus is beautiful. The glass is of the best quality. . . ." The adjustments, however, were all wrong.

> "My impression is," he writes, "that in the north lighthouse three-fourths of the light is absolutely thrown away, and in the south lighthouse nine-tenths of the light is absolutely thrown away. . . . When with a ruler I covered the part of the flame which merely gave light to the sky, it was absurd to see how little was left for the useful part. . . . It really gave me a feeling of melancholy to see the results of such exquisite workmanship entirely annihilated by subsequent faults in the mounting and adjustment."

In the end, Mr. Chance was given a free hand.

Airy again reports, at a later date,

> "The said constructor"—Mr. Chance—"is willing to go heartily into the improvement of the Whitby light, therefore leave all others and rest on it."

And this wise advice was taken.

A method of adjustment—it seems sufficiently obvious, and had been used previously—was suggested by Airy and employed in setting up the lenses. Each portion of the lens system is to be employed in forming an image of some part of the lamp flame on the distant horizon or on some part of the sea between the lighthouse and the horizon. Conversely, if the adjustment is correct, a real image of that part of the horizon will be formed by the lens system on the corresponding part of the flame, and can be seen by an observer looking into the lens system from behind.

Airy's method consisted in adjusting the lenses in turn until the image of the horizon formed by each occupied its proper position with regard to the flame.

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It is clear that the adjustment will depend in part on the position of the lighthouse, especially on its height above sea-level, and that a system of lenses put together without any reference to this was bound to be wrong.

The results were entirely satisfactory, and the Whitby light when reconstructed gave admirable results.

A good deal of correspondence followed with some members of the Commission as to the form of lamp and the best height for the principal focus of the system above the wick, and as time went on various other improvements were introduced; but Mr. Chance's position was now assured, and is evidenced by the long list of splendid lights we owe to him.

One of the improvements worked out in collaboration with Mr. Thomas Stevenson is the dioptric mirror, whereby the rays which leave the lamp at the back are totally reflected by suitable curved prisms and issue in the direction in which the light is required to travel.

The whole book, however, is most interesting, and forms a striking illustration of the application of science to industry. Mr. Chance realised the need of this, and his success was the consequence.

His contributions to the mathematical side of the subject are summed up in two papers read before the Institution of Civil Engineers in 1867 and 1879. The first deals with lighthouses in general; its value as a reprint is, however, impaired by the omission of the careful figures by which it was illustrated; in the second, the question of the application of the electric light to lighthouses is considered. Electric light was employed at the South Foreland in 1872 and at the Lizard lighthouse in 1878. The apparatus in the latter case was designed by John Hopkinson, who on Mr. Chance's retirement became scientific adviser to the firm. R. T. G.

THE INFINITIES OF MATHEMATICS.

Die Grundsätze und das Wesen des Unendlichen in der Mathematik und Philosophie. Von Dr. Phil. Kurt Geissler. Pp. viii + 417. (Leipzig: Teubner, 1902.) Price 14 marks.

EVERY serious inquiry leads, sooner or later, to metaphysics, and thus to antinomies which no merely logical process can reconcile. The pure mathematician is one of the first to reach this conclusion, because his methods are mainly logical, and the notions with which he deals are few and abstract. Why is it, then, that (as a rule) he regards the philosopher with a mixture of pity and disdain, and rarely takes part in any strictly metaphysical discussion? Each is vitally concerned with number, space and time; why do the conclusions of the one appeal so little to those of the other? Leaving the philosopher to answer for himself, we may endeavour to construct the mathematician's apology.

It is mainly that, while he reaches the fundamental paradoxes as soon as the metaphysician, his attitude towards them is different. As it seems to him, the philosopher, after an imperfect analysis, tries to save the situation by a still more imperfect transcendental synthesis. To swamp all distinctions in the Absolute, while assuring us that the distinctions persist, is a childishly simple course, especially when adopted by someone who has a very vague conception of the distinctions which he proposes to abolish. Surely it is reasonable to examine our concepts as carefully as we can, to discover, if possible, which are simple and which are derived or composite. Until we do this, we have no right to say what are the ultimate logical inconsistencies, still less how we propose to reconcile them. The presuppositions of arithmetic and geometry have recently been analysed with great care, and definite results of primary importance have been obtained; the philosophical bearing of these conclusions is obvious, and henceforth no metaphysical theory that ignores them will be accepted by mathematicians. Difficulties remain, of course; some have emerged which were previously unsuspected; but at any rate the ground has been cleared of many merely sophistical paradoxes, and the real issues have been made clearer.

Dr. Geissler's book is rather pathetically disappointing; he has evidently tried to master modern critical theories, but has failed in the attempt. The whole arrangement of the work is unsatisfactory, starting as it does with a vague spatial intuition, and constantly mixing up arithmetical difficulties with those of geometry. In the forefront of all discussions of mathematical infinity must be put the notion of the arithmetical continuum; this, at any rate, is precise and definite. From it we get the concept of a continuous real variable, and thence can proceed to the differential and integral calculus treated by the method of limits. This involves the use of a fluent differential, but there are no serious logical difficulties. Dr. Geissler's attitude is anything but precise, and not always consistent; he appears to try to establish the existence of infinitesimals of different orders as actual entities, and this partly by geometrical considerations. In this region of thought geometrical intuition is wholly untrustworthy; and it is doubtful whether any satisfactory analytical theory can be constructed on the basis of what we may call fixed infinitesimals. It is certain, for instance, that in the arithmetical continuum there is no natural series of orders of infinitesimals. What is the precise nature of geometrical continuity, and how far it can be expressed by arithmetical means, is a very difficult question, upon which Dr. Geissler does not help to shed any light.

One important point the author does emphasise, though sometimes with more zeal than discretion. The terms *infinite* and *infinitesimal* have no precise meaning except in relation to a context and to certain presuppositions. Thus, in projective geometry, the statement that all points at infinity lie in a plane is a convenient summary of a set of facts about parallels; on the other hand, in the theory of algebraic functions, we assume that in the plane of the complex variable there is only a single point (not a line) at infinity. Each statement is true in its context, and out of its context it means nothing at all. If, with Dr. Geissler, we set off equal finite segments continually along a Euclidean straight line, we may assert the possibility of any

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